PEACE/WILLISTON
FISH & WILDLIFE
COMPENSATION
PROGRAM

BCHydro

BRITISH
COLUMBIA

Davis River Bull Trout Radio Telemetry Studies, 1999 Final Report

D. S. O'Brien and J. T. Zimmerman
April 2001

PWFWCP Report No. 236

105-02352/

The Peace/Williston Fish & Wildlife Compensation Program is a cooperative venture of BC Hydro and the provincial fish and wildlife management agencies, supported by funding from BC Hydro. The Program was established to enhance and protect fish and wildlife resources affected by the construction of the W.A.C. Bennett and Peace Canyon dams on the Peace River, and the subsequent creation of the Williston and Dinosaur Reservoirs.

Peace/Williston Fish and Wildlife Compensation Program, 1011 Fourth Ave. 3rd Floor, Prince George B.C. V2L 3H9

Website: *www.bchydro.bc.ca/environment/initiatives/pwcp/*

This report has been approved by the Peace/Williston Fish and Wildlife Compensation Program Fish Technical Committee.

Citation: D. S. O'Brien and J. T. Zimmerman. April 2001. Davis River bull trout radio telemetry studies, 1999 final report. Peace/Williston Fish and Wildlife Compensation Program, Report No. 236. 21pp plus appendices.

Author(s): Dave S. O'Brien[1] and J. Ted Zimmerman[1]
Address(es): [1] Ministry of Environment, Lands and Parks, 1011 Fourth Ave. 3rd Floor, Prince George, B.C. V2L 3H9

Davis River Bull Trout Radio Telemetry Studies

1999 Final Report

D.S. O'Brien and J.T. Zimmerman[1]

[1]Ministry of Environment, Lands and Parks
325, 1011 4th Ave.
Prince George, B.C. V2L 3H9

April 2001

Citation: D.S. O'Brien and J.T. Zimmerman 2001. Davis River bull trout radio telemetry studies: 1999 final report. Peace/Williston Fish and Wildlife Compensation Program Report No. 236. 21pp plus appendices.

This report has been approved by the Peace/Williston Fish and Wildlife Compensation Program Fish Technical Committee.

ABSTRACT

Twenty-five bull trout were radio tagged at the mouth of or in the Davis River (tributary to Williston Reservoir, Peace River system) from 24 June to 3 August 1999. The majority of bull trout were captured by angling in the mainstem Davis River. Three bull trout captured in Graham Lake (Davis River headwaters) were also radio tagged, bringing the total number tagged to 28. Ten of the tagged bull trout had temperature sensitive radio tags, which transmit the temperature of the tag with a variable transmission pulse rate. Bull trout were tracked migrating to destinations in the Davis River mainstem, Davis River tributary 616, the Graham River mainstem, Graham River tributary 657, and the Chowika River. A large proportion of the radio tagged bull trout (>28%) were located less than 4 times, and likely remained in deep water where they could not be detected. Fourteen percent of radio tagged bull trout were consistently located, but moved little from their tagging locations, suggesting mortality. Bull trout migrations within Davis River, excluding those tagged in Graham Lake, were very similar. On average, Davis River migrants arrived at spawning locations on 28 August after an immigration (post-tagging) of 31 days, remained there for 11 days and began emigration from the system on 9 September. All individuals tagged in the Davis River or in Davis Bay making spawning migrations into the Davis River were tracked to, or are presumed to have returned to, the Williston Reservoir. Bull trout tagged in Graham Lake were smaller, arrived at spawning locations earlier, and remained at spawning locations longer than Davis River migrants. The Graham Lake tagged bull trout also returned to Graham Lake after spawning, suggesting separation from the Davis River migrants. The timing of the beginning of spawning site residency in the Davis River is the same as the timing observed in the Duncan and Adams rivers; however, the length of residency at spawning sites was roughly two thirds shorter (11 *vs.* 31 days) for Davis River migrants. On average, bull trout carrying temperature sensitive radio tags were $>1^{0}$C warmer than the predicted ambient stream temperatures derived from eight temperature loggers located throughout the system.

ACKNOWLEDGEMENTS

We would like to acknowledge the assistance of the following individuals in assisting with this work : Andrew Wilson, Ray Pillipow, and Don Cadden assisted with the fieldwork, and Scott Keillo provided the aluminum boat used to access Davis Bay. This project was jointly funded by the B.C. Watershed Restoration Program and the Peace Williston Fish & Wildlife Compensation Program.

TABLE OF CONTENTS

ABSTRACT II

ACKNOWLEDGEMENTS II
TABLE OF CONTENTS III

TABLE OF FIGURES IV

TABLE OF TABLES IV

INTRODUCTION 5

METHODS 6

CAPTURE 6
TELEMETRY 7
TEMPERATURE 9

RESULTS AND DISCUSSION 11

CAPTURE 11
TELEMETRY 13
TEMPERATURE 16

CONCLUSIONS 19

RECOMMENDATIONS 20

REFERENCES 20

APPENDICES 22

APPENDIX 1. MOVEMENT STATISTICS 22
APPENDIX 2. TEMPERATURE ANALYSIS DATA 23
APPENDIX 3. INDIVIDUAL MOVEMENT PATTERNS 24

Table of Figures

Figure 1. The Davis River bull trout telemetry study area 6
Figure 2. A hypothetical migration pattern showing the function of the residency mark in defining the boundaries between the three migration phases. 9
Figure 3. The location of fixed temperature loggers in the Davis and Chowika river systems. 10
Figure 4. Example calculation of the deviation (D) in temperature of a STO radio tag temperature fix, from the predicted temperature derived using the linear relationship between upstream and downstream temperatures from fixed loggers. 11
Figure 5. Fork length - mass relationship of all bull trout captured and measured in 1999 (n = 50). The relationship is explained by the equation logMass(g) = 3.043 * logFL(mm) - 5.201 (r^2 = 0.988) 12
Figure 6. The location of all reception data collected in 1999 17
Figure 7. Average weekly temperature data collected from temperature loggers placed in the Davis River (see Figure 3 for locations). 18
Figure 8. The average daily temperature at temperature loggers placed near known spawning locations with the average timing of the residence phase of bull trout tracked to destinations in the Davis River. 18

Table of Tables

Table 1. Date, location and result of bull trout capture effort 12
Table 2. Summary of radio tagged bull trout data 14
Table 3. The number of bull trout classified in each destination category and the ANOVA analysis groups 15
Table 4. Results of migration statistic * destination ANOVA 15
Table 5. Davis River migration statistic comparisons with combined Duncan and Adams River data (O'Brien and Chamberlain 2000) 16

INTRODUCTION

The Davis River (56^0 32' 53" N 124^0 28' 31" E, Figure 1) is a fifth order stream located in the Peace River drainage, which flows southwest into the Finlay Reach of Williston Reservoir. Adfluvial bull trout (*Salvelinus confluentus*) from Williston Reservoir utilize the Davis River for spawning. Aerial and ground surveys in 1998 identified specific locations of bull trout redds in the Davis River system (Ted Zimmerman, unpublished data). In addition, 1998 redd location data was analysed in relation to habitat features scored from an aerial videography survey conducted in 1997 (Ramsay 1999). These studies identified the Davis River as an ideal study system for bull trout research in the catchment of the Williston Reservoir. The Davis River presents a rare opportunity to study questions about bull trout in a natural river system with no current direct anthropogenic impacts.

Bull trout have gained recent research attention based on range-wide evidence of population level declines (McPhail and Baxter 1996). Recent listing of US populations of bull trout under the US Endangered Species Act, and their listing in BC as vulnerable and of special concern (blue-listed, B.C. Conservation Data Centre) has also increased interest. At the time of writing, bull trout were the only fish species identified by the BC Forest Practices Code as requiring special management practices (Haas 1998). As such, data collected from wild river systems are critically important in providing "baseline information," for use in developing prescriptions for restoration activities as well as assessing the effects of anthropogenic disturbance in other locations.

To better understand the utilization of the Davis River by adult adfluvial bull trout, a radio telemetry study was initiated in 1999. Specific questions to be addressed by the 1999 telemetry project were:

- What is the migratory timing of adult bull trout in Davis River?
- What is the spawning distribution of adult bull trout in the Davis River?
- What role does temperature play in the selection of spawning locations by bull trout?
- Do bull trout actively search out cool water sites for migration and spawning?

This report presents a summary of the 1999 telemetry component of the ongoing bull trout studies in the Davis River. Through the analysis of conventional telemetry data, stream temperatures, and the temperatures gathered from bull trout implanted with temperature sensitive tags, we evaluate the four research questions outlined above. As well, we compare these data to similar data collected from other locations in British Columbia.

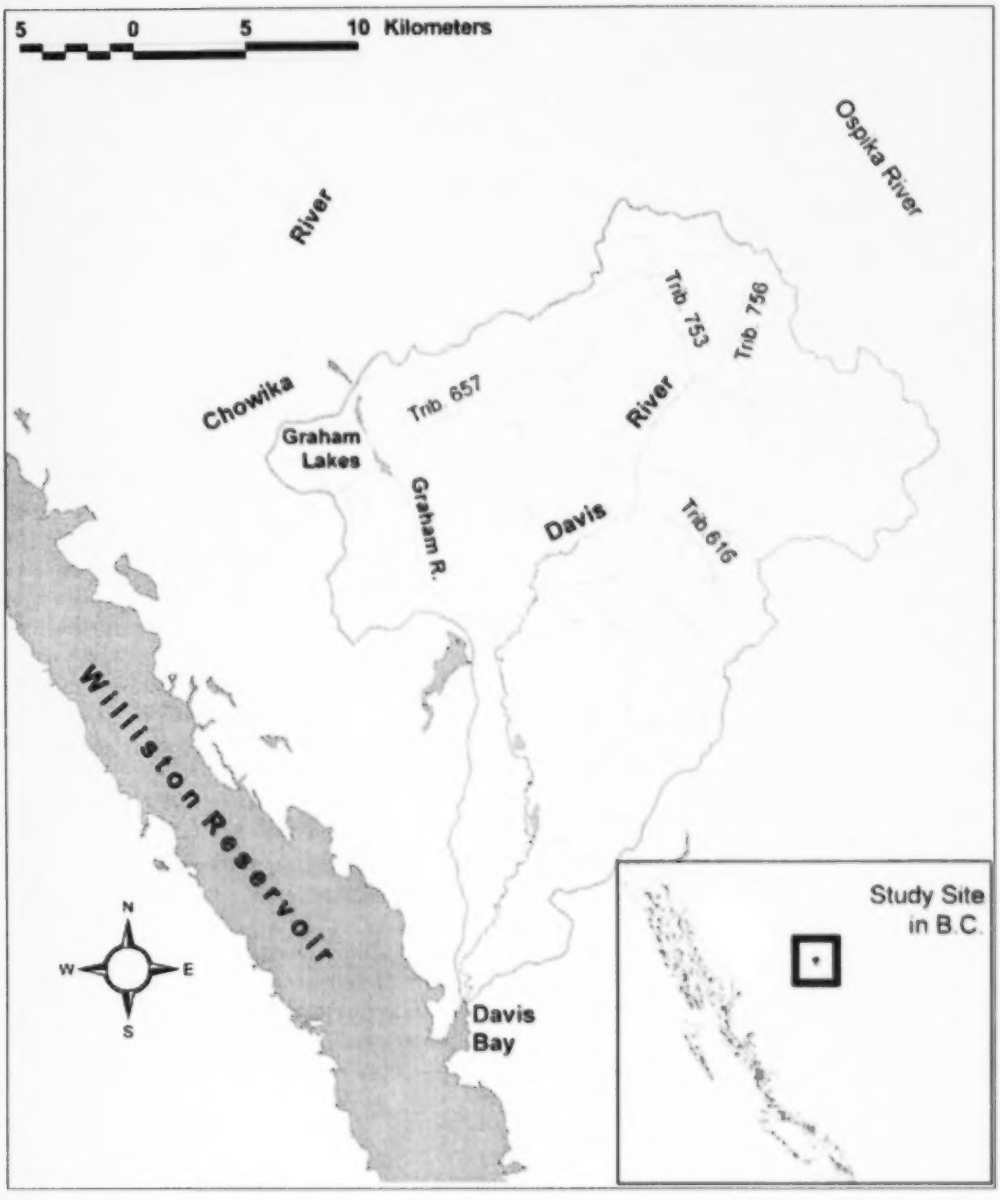


Figure 1. The Davis River bull trout telemetry study area.

METHODS

Capture

Bull trout were captured for radio tagging during two separate capture periods in 1999. In the first capture period, from 24 June to 2 July 1999, bull trout were acquired by angling in Davis Bay and Davis River, with set lines in Davis Bay, and by deploying gill nets in Graham Lake (Figure 1). The second capture period, 29 July to 3 August, involved primarily angling in

Davis River, but also included limited set line activity in Davis Bay and the Davis River. In addition, a 3 hr angling effort in the Chowika River occurred during the second capture period. Access to all locations other than Davis Bay was by helicopter. We accessed Davis Bay using a 3.5m aluminum boat with a 10hp outboard.

Captured bull trout were placed in collapsible fish tubes and anchored in the river or lake until they were processed. All fish processing took place on the riverbank or lakeshore near the capture site. Bull trout were anaesthetized lightly and then tagged with individually numbered Floy (t-anchor) and passive integrated transponder (PIT) tags, measured for both fork length (FL) and mass, sexed (when possible), and sampled for tissue and scales. The anaesthetic bath consisted of a 1211 Rubbermaid tub with a lid, containing 50l of water with 100ppm tricane methane sulfonate buffered with 100ppm sodium bicarbonate. Tissue and scale samples were stored in individual 1.5ml centrifuge tubes containing 95% ethanol. If captured bull trout were deemed too small to be equipped with a radio tag (< 500mm), they were held in the current until fully recovered, then released. Bull trout > 500mm were left in the anaesthetic bath and anaesthetized to a level suitable for surgery (McKinley, Power *et al.* 1992). Other captured fish species were measured and recorded, but we did not apply tags or collect tissue or scale samples.

Telemetry

The radio tags used in this study were manufactured by Lotek Engineering Ltd., of Newmarket, Ontario. We used two tag models: the MCTF-3A, which is a digitally encoded, 5s pulse-interval radio transmitter, and the STO-3, which is temperature sensitive and transmits temperature data as a variable pulse interval to the receiver. Each STO-3 tag was calibrated at the factory to an accuracy of $\pm 0.2^{0}$C. The MCTF-3A tag measured 16mm in diameter, 51mm in length, weighed 6.2g in water, and had an estimated operational life of >680 days. The STO-3 tag was 14.5mm in diameter, 48mm in length, weighed 4.4g in water and had an operational life of approximately 280 days depending on temperature. Both tag models transmitted via a 400mm whip antenna.

Throughout this report, bull trout tagged with MCTF-3A tags are identified by the unique channel-code combination of their radio tag, preceded by 'RT'. For example, a fish tagged with an MCTF-3A tag, code 120, and transmitting on channel 8, is referred to as 'RT 8-120'. All of the MCTF-3A tags transmitted on one of five channels: 8, 9, 11, 14 or 25 (149.460, 149.480, 149.520, 149.580 and 149.800 MHz respectively). Each STO-3 tag transmitted on its own frequency, and throughout the report these tags are identified by their individual frequency (three digit kHz, as all were within 149 MHz - i.e. 149.###) preceded by 'S'. For example, an STO-3 tag transmitting at 149.619 MHz, is referred to as 'S-619'.

We radio tagged all bull trout captured with a FL > 500mm. By tagging bull trout that exceeded this length, we kept the tag (in water) to fish (in air) weight ratio below 1%, as recommended in Marty and Summerfelt (1986) and McLeod and Clayton (1993). The surgical procedure followed the method described by McLeod and Clayton (1993). Anaesthetized bull trout were oriented on their back in a wet neoprene-lined surgical trough. A 2.5 cm incision into the abdominal cavity was made on the mid-ventral line immediately anterior to the pelvic girdle. We then inserted a 16guage, 5cm long stainless steel needle into the incision by piercing the body wall posterior to the pelvic girdle and pushing the needle through the incision point. The whip antenna of the radio tag was guided through the needle, the needle was removed, and the tag was inserted into the abdominal cavity. The incision was closed with three or four interrupted sutures. Betadine was applied to the closed incision and antenna exit wound. After the procedure, tagged bull trout were transferred from the surgical trough to the river and were held in the current until recovery. When the fish was capable of maintaining equilibrium, it was placed back into a collapsible fish tube and allowed to further recover for 10 - 30 min. before release.

A Lotek SRX-400 receiver was used to track radio tagged bull trout from a helicopter. A two-element Yagi antenna ('H' antenna), oriented forward and parallel to the horizon, was attached to the helicopter skid assembly. A Bell 206 (Jet Ranger) was used for tracking during

capture periods, and either a Robinson R44 or Robinson R22 were used for tracking once all fish had been tagged. All receptions were recorded as a channel-code combination (MCTF-3A tags) or as a frequency and temperature combination (STO-3 tags). A written description, and a UTM coordinate were logged for each located fish. Positions were captured using either a Trimble "ProXR" or Trimble "Geo 2" GPS unit. Coordinate locations were subsequently corrected to an accuracy of ± 20m with differential correction software.

We used river kilometre designations that were previously created for the Davis River mainstem (T. Zimmerman, unpublished data), extended them for locations where they did not exist (Davis River tributaries and the Chowika River), then analysed the telemetry results using ARCVIEW™ software. We converted differentially corrected reception points to their respective river kilometre locations for analysis. The analysis followed the methods of O'Brien (1999). First, we plotted the reception locations for each tagged individual as a date *vs.* kilometer location. Then we divided each individual movement plot, when possible, into three distinct phases: immigration, 'spawning' site residence, and emigration. It is important to note that spawning surveys did not take place in all 'spawning' residency locations, and as such the term is used for clarity only. The immigration phase began when a bull trout was tagged and it continued upstream until this directed movement ceased. The spawning site residence phase continued from the end of the immigration phase until the start of a directed downstream movement. The emigration phase lasted until the fish was no longer detected, or until the tagged bull trout had returned to the Williston Reservoir.

To simplify and standardize these data, we categorized bull trout migrating to similar locations, and for each destination category an arbitrary location was used to distinguish between the three migration phases. This arbitrary 'residency mark' was positioned to include all similar migrants to a particular destination and was based on the cessation of directed upstream movement. For example, when a radio tagged bull trout migrating to tributary 657 of Graham River crossed the 35.3km mark, we considered it to have begun its spawning site residency phase. The date the residency mark was crossed was inferred from the closest receptions immediately upstream and downstream. The division of individual movement patterns into these phases (Figure 2) allowed the calculation of nine migration statistics (O'Brien 1999):

- immigration start date, time (d) and rate (km/d)
- spawning site residency start date and time (d)
- emigration start date, time (d), rate (km/d) and end date

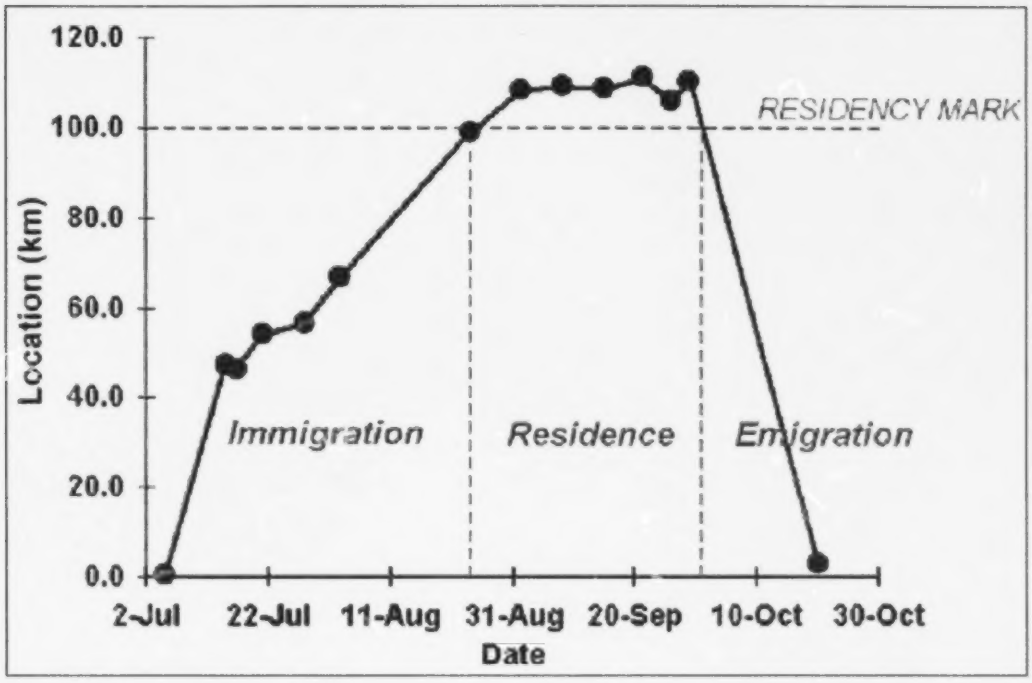


Figure 2. A hypothetical migration pattern showing the function of the residency mark in defining the boundaries between the three migration phases.

We compared seven of the nine migration statistics, along with FL and mass, by destination category using single factor analysis of variance (ANOVA). As discussed in O'Brien (1999), immigration and emigration rates are confounded with destination category and are calculated, but not compared using ANOVA. Because of our small sample size, we grouped destination categories into broad groups for analysis. Where no significant differences existed in migration statistics between destination groups, we pooled the data. When differences between destination groups were detected by ANOVA, we did a multiple comparison using a Tukey test (Zar 1996) to determine the relationships between destination groups, then pooled those destination groups that were not different. We then used a t-test to compare the combined data with data from the Duncan (O'Brien 1999) and Adams rivers (O'Brien and Chamberlain 2000). Because of differences in methods used in this study and those employed in the Duncan and Adams studies, we only compared three of the migration statistics: residency start date, length of the residency phase, and residency end date. All statistical calculations were made using the SYSTAT™ software package.

Temperature

Temperature data were collected from eight locations in the Davis, Graham and Chowika rivers (Figure 3) using Onset Optic Stowaway® temperature loggers accurate to ±0.25°C. The temperature loggers were housed in cylindrical aluminum casings (180mm L x 40mm ID) and attached to the end of a 10m length of 95mm chain. The other end of the chain was attached to the riverbank, usually locked around a tree. Temperature loggers were programmed to collect hourly stream temperatures after they were deployed; data was collected at 3 sites starting on 22 September 1998, while the remaining 5 loggers were deployed on January 26, 1999. This report presents temperature data collected until 14 October 1999, focusing on temperatures collected during the period that temperature data from STO radio tagged bull trout was also collected.

To compare the temperature data collected from radio tagged fish with stream temperatures collected by fixed temperature loggers, we predicted the stream temperature at the sites where STO-equipped bull trout were located, then compared this temperature with the actual fish temperature derived from the radio tag. To predict the stream temperature at the site where a fish was located, we assumed that there was a linear relationship in temperature between the two fixed loggers that bracketed the radio tagged fish. By using the time when the STO radio tag fix was recorded, we were able to extrapolate the associated stream temperature from the linear function, based on the closest hourly record of temperature at each of the two fixed loggers. We then calculated the deviation between the actual temperature and that predicted by the temperature loggers (Figure 4), then calculated the average of these deviations.

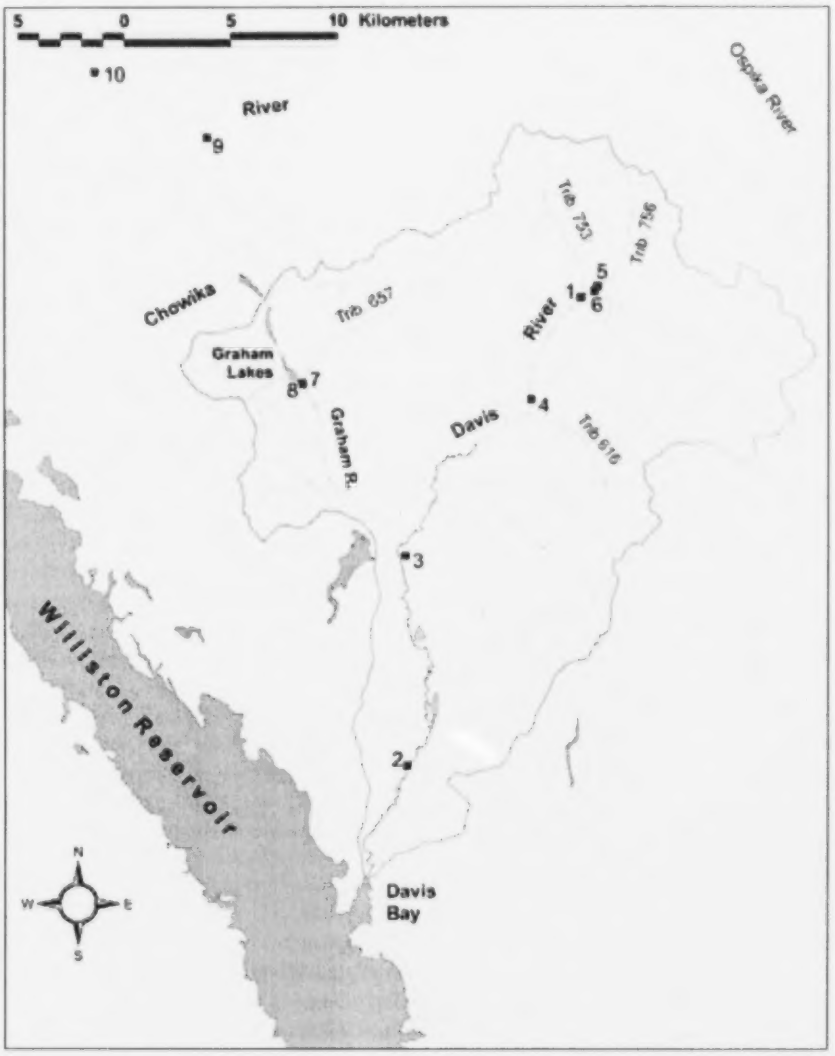


Figure 3. The location of fixed temperature loggers in the Davis and Chowika river systems.

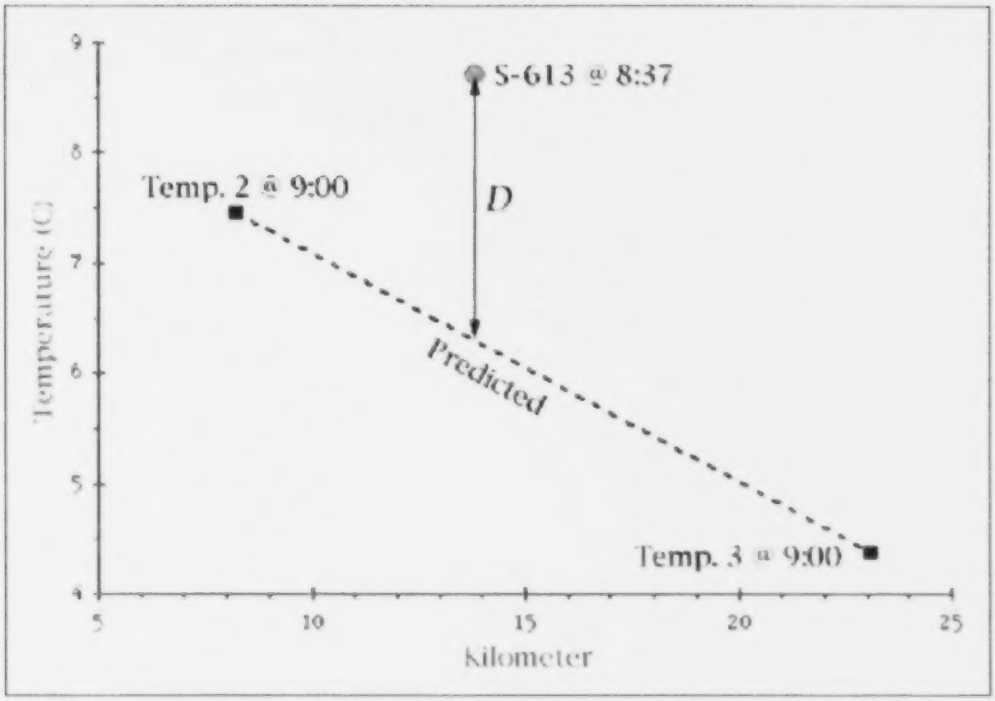


Figure 4. Example calculation of the deviation (D) in temperature of a STO radio tag temperature fix, from the predicted temperature derived using the linear relationship between upstream and downstream temperatures from fixed loggers.

RESULTS AND DISCUSSION

Capture

The capture effort and capture results for bull trout are summarized in Table 1. Angling was the most successful capture technique, particularly in late July and early August in the mainstream Davis River. Although not reflected in CPUE (Table 1), setline effort in Davis Bay in late June and early July was also productive in obtaining bull trout of radio tagging size (>500mm). The fork length - mass relationship of captured bull trout is presented in Figure 5.

Table 1. Date, location and result of bull trout capture effort.

Date	Location	Type	Effort (Hrs)	BT captured	Radio tagged	CPUE	Mean FL (mm)
28 June - 2 July	Davis Bay	Setline	222.50	13	10	0.03	683
29 - 30 June	Davis River	Setline	260.65	0		0.00	n/a
30 - 31 July	Davis River	Setline	177.15	0		0.00	n/a
24 June - 29 June	Davis Bay	Angling	32.52	7	1	0.22	750 [A]
29 June	Davis River	Angling	0.60	0		0.00	n/a
30 June - 1 July	Graham L.	Angling	12.03	7	1	0.58	525 [B]
30 June	Graham R.	Angling	0.50	0		0.00	n/a
30 July - 2 Aug.	Davis River	Angling	22.81	56	14	2.46	638 [C]
2 August	Chowika R.	Angling	3.00	11		3.67	688 [D]
30 June - 1 July	Graham L.	Gillnet	8.85	6	2	0.56	502

[A] only one bull trout measurement recorded (6 released without tagging/measurement,<450mm)
[B] release 4 bull trout without tagging/measurement (<450mm)
[C] one bull trout escaped before measurement
[D] 1 bull trout released without tagging/measurement (<450mm)

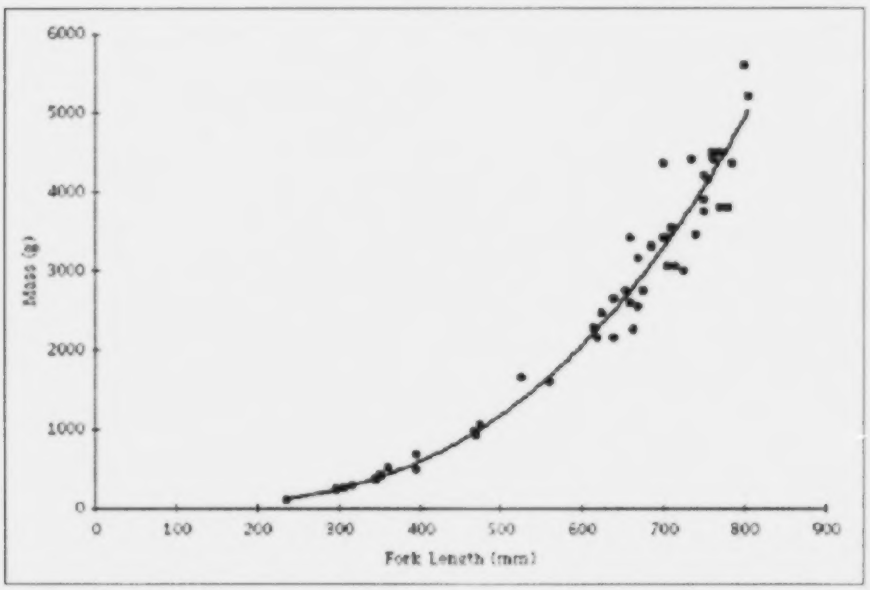


Figure 5. Fork length - mass relationship of all bull trout captured and measured in 1999 (n = 50). The relationship is explained by the equation logMass(g) = 3.043 * logFL(mm) - 5.201 (r^2 = 0.988)

Angling was particularly successful in late July and early August (Table 1). The capture rate of 2.46 BT/rod hour in the Davis River (Table 1) is higher than angling CPUE reported in other studies (e.g. 0.20 in the Adams River, BC (O'Brien and Chamberlain 2000); 0.32 in the Clearwater River, Alberta (Rees 1992); 1.82/rod hour in the lower Duncan River, BC (Olmsted and den Biesen 1998). The 3.67 BT/rod hour in the Chowika River (Table 1) reflects capture rates only limited by handling, measuring and tagging time.

The fork length * weight relationship (logMass(g) = 3.043 * logFL(mm) - 5.201) determined for Davis River captures (n = 50) is very similar to other such equations from British Columbia adfluvial bull trout populations. For example, O'Brien (1999) found a relationship of logMass = 2.941 * logFL - 4.845 (n=123) in adults from the Duncan River, and Baxter (1996)

found that logMass = 3.015 * logFL - 5.006 (n = 350) described the fork length * weight relationship in adults and juveniles from the Chowade River.

Telemetry

In total, we radio tagged 28 bull trout in 1999. On average, each bull trout was located 5.8 times (min. 1 - max. 10 receptions), and tracked moving an average 25.6km (min. 0 - max. 87.6km). The date and locations of tagging are summarized in Table 2. We tagged 10 bull trout with temperature (STO) tags, and received on average 5.2 temperature fixes from each (min. 1 - max. 8 temp. fixes). The mortality rate attributed to the surgery process (as opposed to post-angling mortality) was 11%, or 3 of the 28 fish. This rate is somewhat higher than that reported by O'Brien (1999, 3% over 6 months), and by O'Brien and Chamberlain (2000, 5% over four months). However, radio tagged bull trout survival over the spawning period has been reported to be as low as 33% (Schill *et al* 1994).

Of the 28 bull trout tagged during this study, 12 (Table 3 Categories 1 & 2) were either detected less than 3 times, or showed no signs of movement after tagging. Of these 12 fish, 4 were subsequently confirmed to have died, one of which was killed by an angler. A fifth fish was recaptured and released by an angler the day after it was tagged, but exhibited no movement thereafter and is presumed to have died. Two of the 12 bull trout were detected upstream of their tagging location approximately one month after they were tagged, but were not detected during subsequent flights, indicating that they had survived the surgery but had then moved out of the Davis system. The remaining 5 trout, all of which were tagged in Davis Bay, were not detected after tagging and are presumed to have remained in the reservoir or to have moved into other tributaries.

Thirteen trout were captured and 11 were tagged in Davis Bay during the first sampling session from June 28 to July 2, 1999. While it was recognized that fish released from this location might migrate back into the reservoir, we felt that the likelihood of migration into the Davis River remained high enough to warrant deploying tags at the site. In addition, 370 hours of setline effort yielded no fish in the Davis River, while a concurrent effort of 222 hours of setline sampling in Davis Bay yielded 5.9 bull trout per 100 hook-hours, suggesting that staging fish had reached the bay but had not entered the river. However, of the 11 Davis Bay fish that were equipped with tags, only 2 were eventually tracked to spawning locations: one in the Davis and the other in the Chowika River (Figure 6). Two fish were confirmed as mortalities, while the remaining 7 either disappeared immediately after tagging or within one month of tagging. This suggests that the fish acquired from Davis Bay during the first sampling session were not necessarily staging to spawn in the Davis River, but perhaps were residing at the mouth of the river to take advantage of food supplies available at during that time.

Table 2. Summary of radio tagged bull trout data.

Radio Tag	Tagging Date	Tagging Location	River Km	FL (mm)	Mass (g)	Floy Tag	PIT Tag	Sex
S-599	01 Jul	Davis Bay	0	700	4350	2987	401D65616B	F
S-619	1 Aug	Davis R.	13.9	805	5200	2958	401D695A1C	M
S-640	1 Aug	Davis R.	13.9	710	3550	2956	401D65750F	M
S-660	1 Aug	Davis R.	13.9	750	4200	2954	401D4E7C59	M
S-680	2 Aug	Davis R.	19.3	685	3300	2848	401D540447	F?
S-701	2 Aug	Davis R.	8.1	780	3800	2849	401D6B5530	M
S-719	02 Jul	Davis Bay	0	770	4500	2991	401D4D4411	M
S-740	02 Jul	Davis Bay	0	740	3450	2989	401D611163	M
S-761	2 Aug	Davis R.	19.3	750	3900	2846	401D745740	M
S-779	30 Jun	Graham L.	35.3	525	1650	2983	401D6D0251	F
RT 8-52	1 Aug	Davis R.	1.6	705	3400	2964	401D6D3E70	M
RT 8-57	01 Jul	Davis Bay	0	735	4400	2988	401D566C1C	M
RT 8-70	28 Jun	Davis Bay	0	750	3750	2951	401D583F30	M
RT 9-58	1 Aug	Davis R.	1.6	755	4150	2962	401D6D601B	F
RT 9-62	02 Jul	Davis Bay	0	785	4350	2992	401D696A61	F
RT 9-75	01 Jul	Davis Bay	0	670	3150	2980	401D6F070F	M
RT 9-78	1 Aug	Davis R.	13.9	640	2150	2959	401D4F7011	M
RT 11-53	01 Jul	Davis Bay	0	625	2450	2981	401D6A4F28	?
RT 11-55	1 Aug	Davis R.	13.9	n/a*	3200	2955	401D613354	M
RT 11-57	1 Aug	Davis R.	1.6	715	3050	2970	401D6B3073	M
RT 11-76	02 Jul	Davis Bay	0	800	5600	2993	401D5D230A	M
RT 14-51	01 Jul	Graham L.	35.3	615	2275	2984	401D62673A	M
RT 14-54	01 Jul	Davis Bay	0	769	3800	2982	401D6E752B	M
RT 14-57	02 Jul	Davis Bay	0	705	3050	2990	401D602607	M
RT 14-69	01 Jul	Graham L.	35.3	620	2150	2985	401D4D3F44	M
RT 25-62	2 Aug	Davis R.	19.3	655	2750	2847	401D6B4F3C	F
RT 25-69	1 Aug	Davis R.	1.6	675	2750	2968	401D502814	M
RT 25-70	1 Aug	Davis R.	1.6	725	3000	2966	401D4C6711	M

*not measured

Viable bull trout were tracked throughout the Davis, Graham, and Chowika rivers. The locations of all receptions are presented in Figure 6, and movement patterns of all bull trout detected more than 3 times are listed in Appendix 3.

We classified the movement patterns of each bull trout into one of 8 categories (Table 3). The most common categories were radio tagged bull trout migrating to destinations in the mainstem Davis River (29%), and those bull trout that were received less than 3 times (29%). The destination and migratory summary data of individual radio tagged bull trout are tabulated in Appendix 1. For ANOVA analysis, small numbers of migrants required the grouping of destination categories (Table 3).

Table 3. The number of bull trout classified in each destination category and the ANOVA analysis groups.

Destination: Category	Description	Number of migrants	Percentage	Analysis group
1	no movement	4	14.3	n/a
2	< 3 receptions	8	28.6	n/a
3	Davis River	8	28.6	1
4	Graham River	2	7.1	2
5	Davis tributary	1	3.6	1
6	Graham tributary	3	10.7	2 + 3*
7	Graham Lake	1	3.6	n/a
8	Chowika River	1	3.6	n/a

*Analysis group dependent on tagging location - see text

We grouped migration data for the analysis based on tagging location (Davis Bay or River, or Graham Lake) and broad scale destination (Graham or Davis River). The migration of only a single fish to the Chowika River precluded it from the ANOVA. In all ANOVA comparisons except one, the migration statistics of bull trout tagged in Davis River or Bay, regardless whether they migrated to destinations in the Davis River or Graham River, were not different (Tukey Test, results summarized in Table 4). Bull trout tagged in the Davis differed in emigration end date depending on their spawning destination: Davis River migrants on average ended their emigration four days earlier (on 11 September) than Graham River migrants (15 September). Bull trout tagged in Graham Lake were significantly smaller, were tagged earlier, began the residence phase earlier, and had a longer residence phase than Davis tagged fish (Table 4). Graham and Davis tagged bull trout did not differ in immigration time or the starting date of emigration (Table 4). The comparisons of emigration end date and emigration time include only the Davis tagged bull trout, as the Graham Lake tagged fish only had to move a very short distance back to the lake.

Table 4. Results of migration statistic * destination ANOVA

Migration statistic*	ANOVA P	Pooled mean	SE	n	Davis River Tagged mean	SE	n	Graham Lake Tagged mean	SE	n
FL (mm)	0.021	Significant differences			728	15	10	617	3.54	2
mass (g)	0.033	Significant differences			3745	235	11	2212	88.39	2
tagging date	0.008	Significant differences			29 Jul	2.85	11	01 Jul	0	2
im. time (d)	0.253	31.3	2.96	13	-	-	-	-	-	-
res. start	0.019	Significant differences			28 Aug	1.84	11	13 Aug.	5.66	2
res. time (d)	0.031	Significant differences			11.4	2.12	9	28.5	4.95	2
em. start	0.671	9 Sept.	1.39	11	-	-	-	-	-	-

* 'im.', 'res.' and 'em.' = immigration, spawning site residence and emigration phases respectively

Because bull trout tagged in Graham Lake were physically distinct and showed slightly different migration timing than the bull trout tagged in the Davis River, we pooled the migration statistics of all the Davis River tagged bull trout for comparison with statistics from other systems (Table 5). It is important to note that due to small sample sizes (i.e. often n=2 in an ANOVA cell), non-significant results should be interpreted with caution.

Interestingly, bull trout tagged in Graham Lake that migrated to spawning locations in tributary 657 of the Graham River all returned to Graham Lake subsequent to spawning. This suggests that the bull trout sampled in Graham Lake may be a separate, resident population from those tagged in the Davis River. Alternatively, the migration of larger bull trout tagged in the

Davis River to the same tributary of Graham River may indicate that bull trout exhibit variable life history patterns with age, or that bull trout spawning at that location exhibit some degree of life history polymorphism.

Table 5. Davis River migration statistic comparisons with combined Duncan and Adams River data (O'Brien and Chamberlain 2000).

Migration	ANOVA	Pooled			Davis River			Duncan/Adams		
statistic*	P	mean	SE	n	mean	SE	n	mean	SE	n
res. start	0.975	26 Aug.	1.09	89	-	-	-	-	-	-
res. time (d)	0.253	Significant differences			11.4	2.21	9	31.9	1.46	64
em. start	0.671	Significant differences			8 Sept.	1.68	9	28 Sep	0.84	64

abbreviations as in Table 4.

The power of the ANOVA was restricted by the small number of radio tagged bull trout migrating to each of the various spawning destinations (Table 3). The primary result was the clear difference between the movements of bull trout tagged in Graham Lake, versus those tagged in Davis River or Davis Bay. The comparison of the Davis data with data from the Duncan and Adams rivers in southern BC highlighted the similar start timing of the residency phase of the migration, and the relative shortness of the residency phase in the Davis (Table 5). Perhaps this reflects an earlier onset of seasonal cues such as temperature, discharge and day length in the Davis River, relative to the Duncan and Adams rivers, as the Davis lies > 5^0 latitude north of these other systems. In the Duncan River, emigration was observed to occur very shortly after water clearing with reduced glacial melt influence in the fall (O'Brien pers. obs.)

Temperature

Temperature data were collected for as long as 387 days (22 September 1998 to 14 October 1999; Figure 7). The average daily temperature for loggers positioned near known bull trout spawning locations are plotted in Figure 8, with the average timing of spawning residency from Davis River migrants noted by the vertical brackets. All three temperature loggers presented in Figure 8 are located within 1.4km of each other (Figure 3).

Comparing the location of temperature loggers (Figure 3) with the mean weekly temperature recorded (Figure 7) revealed a warming pattern as water proceeded downstream in the Davis River during the summer months. This pattern was reversed during the winter months, whereby the loggers located in downstream reaches were the coldest, and those high in the system are as much as 2^0C warmer.

Sensor radio tags (STO-3) were on average 1.17^0C warmer (SE = 0.17, n = 30) than the temperature predicted based on upstream and downstream temperature logger records. This result suggests that our assumption that temperature changes linearly between stations may not hold true. On average, the upstream and downstream temperature loggers were 15.6km apart for individual calculations of sensor tag deviation (Appendix 2). In addition, the temperature reading from the radio tag varied temporally by as much as 30min. from the temperature reading obtained from the temperature loggers. Increasing the number of temperature loggers and recording temperature on a more frequent basis would help to compensate for these potential biases.

The temperature deviation was unexpected given our assumption that bull trout would seek cooler-than-ambient sites during their migration. Given that the Davis River remains cool throughout the year (weekly averages never exceeding 11^0C, Figure 7), bull trout movements may not be constrained by temporal or spatial thermal barriers. In fact, since the Davis River remains relatively cold during the summer, the opposite may by true, i.e. that bull trout actively seek out warm water for migration and spawning.

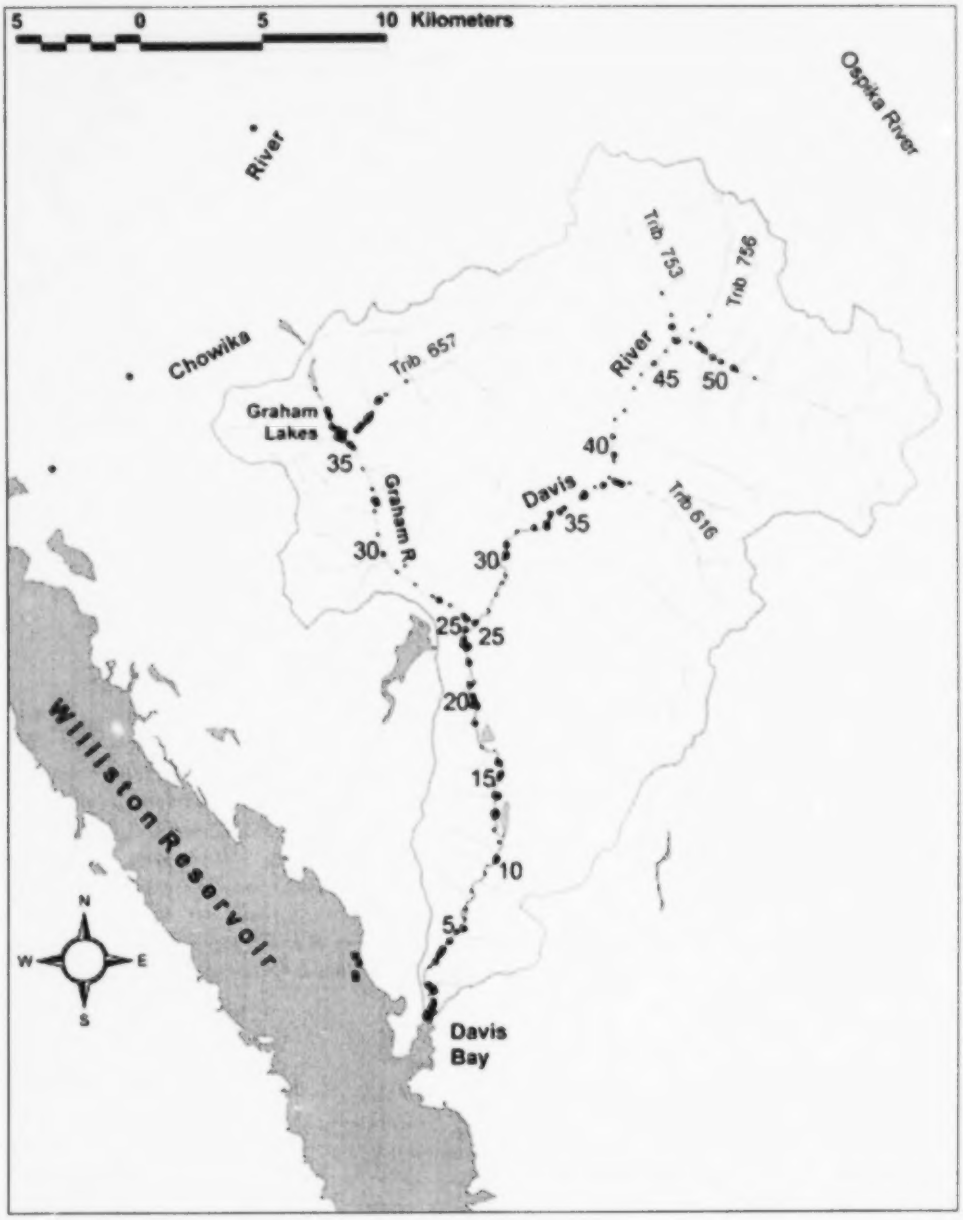


Figure 6. The location of all reception data collected in 1999.

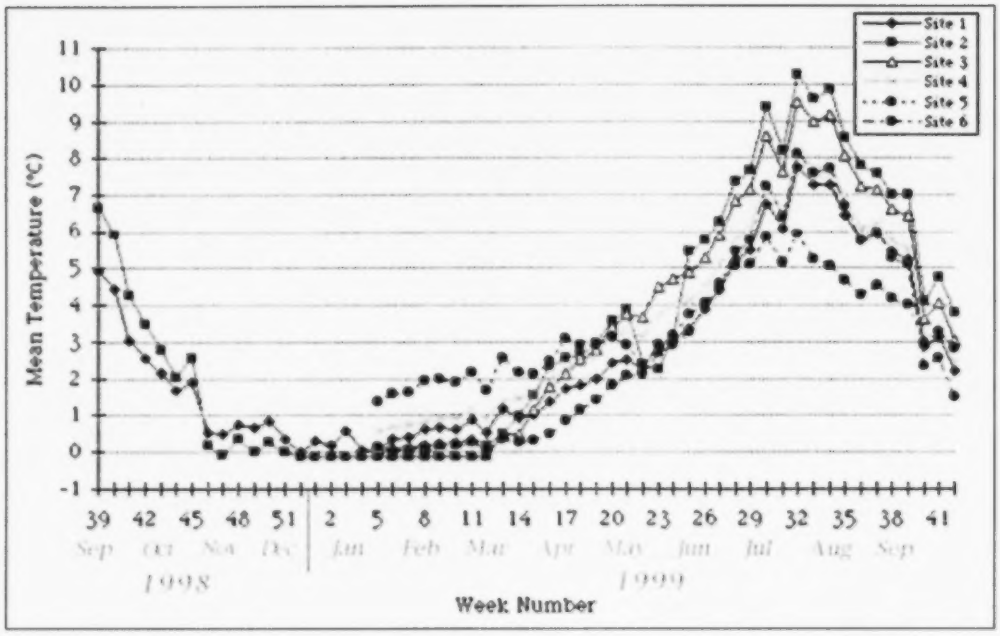


Figure 7. Average weekly temperature data collected from temperature loggers placed in the Davis River (see Figure 3 for locations).

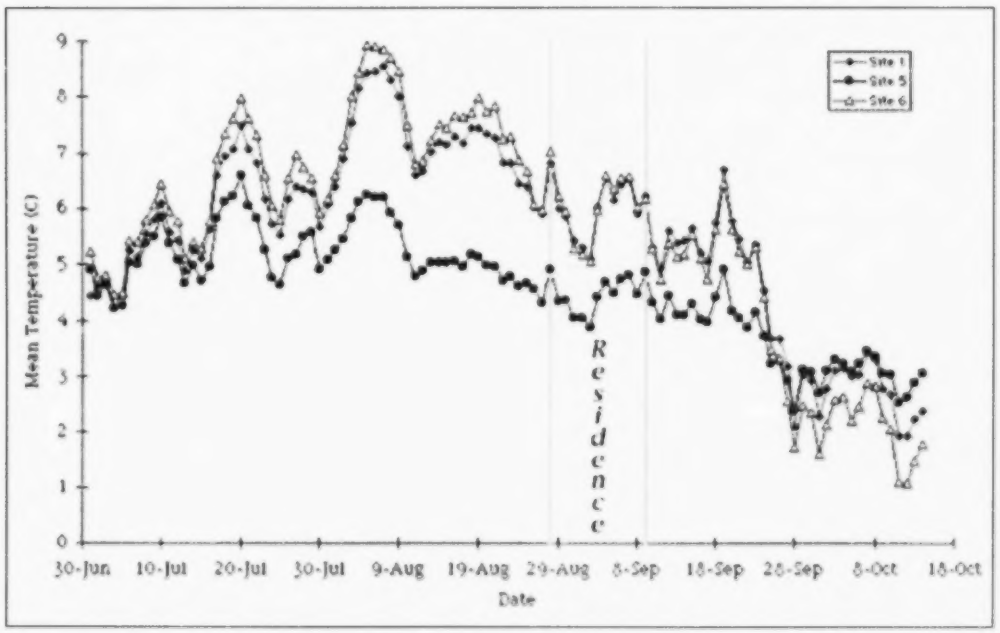


Figure 8. The average daily temperature at temperature loggers placed near known spawning locations with the average timing of the residence phase of bull trout tracked to destinations in the Davis River.

Analysis of the temperature data obtained from loggers located near or at spawning sites (Figure 8) failed to reveal any trends relative to the timing of the residency phase of radio tagged migrants. Clearly, the residency phase occurs during a period of gradual fall cooling of water temperature, but emigration happened well before the sharp drop in temperature in 1999 (Sept. 25 – 28, Figure 8). Bull trout spawning is thought to occur between 9^0 and 5^0 C (reviewed in Baxter and McPhail 1996), which brackets the temperatures observed here (Figure 8) with the exception of Site 5.

Interestingly, the temperature at logger Site 5, located in Tributary 756, shows the greatest temperature stability, suggesting a substantial influx of temperature-moderated groundwater. Yet this site has the lowest use by spawning bull trout of the three sites plotted (Figure 8, Figure 6, Zimmerman pers. obs.). Prior to the sharp drop in temperature, Tributary 756 (logger 5) appears to have little influence on the temperature of the Davis River mainstem (i.e. little temperature difference between logger 6 and 1). However, after September 28, the difference in temperature between logger 6 and logger 1 is more pronounced, with the Davis being slightly warmer downstream of tributary 756. Perhaps the volume of groundwater discharge in Tributary 756 contributes significantly more to mainstem temperatures once flow reduction occurs in the fall. The buffering effect that results from the inflow of Tributary 756 into the mainstem Davis may be partly responsible for the higher utilization of habitat downstream of the confluence.

CONCLUSIONS

- Angling in the mainstem Davis River in late July and early August was the most productive bull trout capture technique.

- Bull trout in the Davis River have a length * weight relationship (logMass(g) = 3.043 * logFL(mm) - 5.201) very similar to other British Columbia adfluvial bull trout populations.

- Three (11%) of the 28 tagged bull trout succumbed to the effects of surgery and died shortly thereafter. An additional 5 (18%) bull trout, all of which were tagged in Davis Bay, did not move into Davis River and are presumed to have moved elsewhere in the Williston Reservoir. Two (7%) of the fish were captured by anglers and were either killed or died from angling related injuries. Two (7%) other fish migrated into the lower Davis River but did not exhibit spawning related movements. One (4%) fish, tagged in Graham Lake, moved within the lake but did not spawn. The remaining 15 (54%) were tracked to spawning locations within the Davis, Graham, and Chowika systems.

- The migration statistics of bull trout tagged in Davis River or Davis Bay did not differ, regardless of destination, except in the timing of the end of the migration (four days later for fish migrating into the Graham River system).

- Radio tagged bull trout showing a migration pattern that were tagged in the Davis River were, on average, tagged on July 29, took 31 days to reach residency locations, arrived on Aug. 28, and remained there for just over 11 days, and began emigration on Sept. 9.

- Bull trout tagged in Graham Lake were significantly smaller, were tagged earlier, began the spawning site residence phase earlier, and had a longer residence phase than bull trout tagged in the Davis River. Graham Lake tagged bull trout also returned to Graham Lake, presumably to overwinter, suggesting a life history separation from Davis River tagged bull trout.

- The Davis tagged bull trout arrived at spawning residence areas at the same time as Duncan and Adams bull trout (26 August), but the residency period was roughly 20 days shorter (11 days *vs.* 32 days).

- Stream temperature changes are not obviously correlated with residency phase timing, but relatively cool and stable water temperatures in tributary 756 may explain both its low use for spawning and the high use downstream of its confluence with the mainstem Davis River.

- Temperature sensing radio tags were on average more than 1^0C warmer than expected based on a linear relationship between upstream and downstream temperature logger data.

RECOMMENDATIONS

- Future tracking efforts would benefit from the placement of a stationary data-logging receiver near the mouth of the Davis River, ideally prior to 15 June. This would help to better describe the timing of immigration and emigration from destinations in the Davis River system.

- Additional stationary data-logging receivers at major stream junctions and a short distance downstream of spawning locations would assist with movement analysis; and would likely be cost effective due to limited access into the Davis system.

- Comparisons between temperature data collected by sensor radio tags and that collected by temperature loggers requires the placement of additional loggers at fixed, short distance intervals (perhaps 1 per km or closer) to allow for a more precise analysis.

REFERENCES

Baxter, J. S. 1996. Chowade River bull trout studies 1995: habitat and population assessment. Prepared for Ministry of Environment, Lands and Parks, Ft. St. John, BC

Haas, G. R. 1998. Indigenous fish species potentially at risk in BC with recommendations and prioritizations for conservation, forestry/resource use, inventory and research. BC Ministry of Environment, Fisheries Management Report No. 105.

Marty, G. D. and R. C. Summerfelt. 1986. Pathways and mechanisms for expulsion of surgically implanted dummy transmitters from channel catfish. Trans. Am. Fish. Soc. 115: 577-589.

McKinley, R. S., G. Power, and H. E. Kowalyk. 1992. Transmitter attachment/implant - laboratory manual. Waterloo, Ont., University of Waterloo, Biology Department.

McLeod, C. and T. Clayton. 1993. Fish Radio Telemetry Demonstration Project, Upper Athabasca River May to August, 1992. Edmonton, Alberta, R.L.&L. Environmental Services Ltd.

McPhail, J. D. and J. S. Baxter. 1996. A review of bull trout (*Salvelinus confluentus*) life-history and habitat use in relation to compensation and improvement opportunities. BC Ministry of Environment, Fisheries Management Report No. 104.

O'Brien, D. S. 1999. The Duncan bull trout telemetry project (1995 -1997). Nelson, BC, The Columbia Basin Fish & Wildlife Compensation Program.

O'Brien, D. S. and M. W. Chamberlain 2000. 1999 Adams bull trout telemetry project - progress report. Prepared for Ministry of Environment, Lands and Parks. Prepared by the BC Conservation Foundation. Kamloops, BC

Olmsted, W. R. and D. den Biesen 1998. Bull trout (*Salvelinus confluentus*) tagging program, lower Duncan River, 1997. Nelson, BC, Ministry of Environment, Lands and Parks.

Rees, K. 1992. Clearwater river bull trout project interim report. Rocky Mountain House, Alberta, Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division.

Schill, D. , R. Thurow, et al. 1994. Seasonal movement and spawning mortality of fluvial bull trout in Rapid River, Idaho, Idaho Department of Fish & Game.

Winter, J. D. 1983. Underwater Biotelemetry. pp. 371-395 in *Fisheries Techniques*. edited by L. A. Nielsen and D. L. Johnson. Bathesda, Maryland, American Fisheries Society.

Zar, J. H. 1996. *Biostatistical Analysis*. Upper Saddle River, New Jersey, Prentice-Hall, Inc.

APPENDICES

Appendix 1. Movement statistics

All statistics used in ANOVA comparisons are shown. Immigration, residency and emigration phases are abbreviated 'imm', 'res' and 'em' respectively.

Tag	# receps	total KM	Destination	Anova	res mark	imm time	imm rate	res start	rest time	em start	em time	em rate	end em KM	end em
S-599	9	74.9	3	1	31	53	0.59	23-Aug	22	14-Sep	14	2.60	0.1	28-Sep
S-619	5	19.7	3	1	31	24	0.71	25-Aug						
S-640	8	24.9	5	1	38	29	0.83	30-Aug						
S-680	9	33.3	4	2	30	34	0.42	4-Sep	5	9-Sep	3	5.60	15.7	7-Sep
S-680	8	76.5	3	1	46	22	1.20	24-Aug	8	1-Sep	12	3.93	1.8	12-Sep
S-701	8	65.5	3	1	46	20	1.12	22-Aug	16	7-Sep	4	9.78	9.9	13-Sep
S-719	2	1.9	2											13-Sep
S-740	1	0	2											
S-761	6	27	3	1	22	17	0.15	19-Aug	12	31-Aug	7	3.29	0.5	11-Sep
S-779	8	6.2	7											
RT 8-52	8	61.1	6	2	35.3	22	1.53	23-Aug	20	12-Sep	1	25.30	12.7	
RT 8-57	1	0	2											13-Sep
RT 8-70	10	6.4	1											
RT 9-58	8	64	3	1	31	31	0.55	1-Sep	7	8-Sep	5	6.04	3.8	
RT 9-62	4	63.2	8		22	56	0.39	27-Aug						28-Sep
RT 9-75	1	0	2											
RT 9-78	8	47.5	4	2	30	35	0.46	5-Sep	3	8-Sep	5	5.78	3.6	13-Sep
RT 11-53	6	7.9	1											
RT 11-55	8	87.6	3	1	46	34	0.94	4-Sep	10	14-Sep	14	3.64	0.1	
RT 11-57	8	1.8	1											
RT 11-76	1	0	2											
RT 14-51	7	10	6	3	35.3	39	0.00	9-Aug	32	10-Sep				
RT 14-54	1	0	2											
RT 14-57	2	3.9	2											
RT 14-69	8	10	6	3	35.3	47	0.00	17-Aug	25	11-Sep				
RT 25-62	7	22.6	3											
RT 25-69	10	2	1											
RT 25-70	1	0	2											

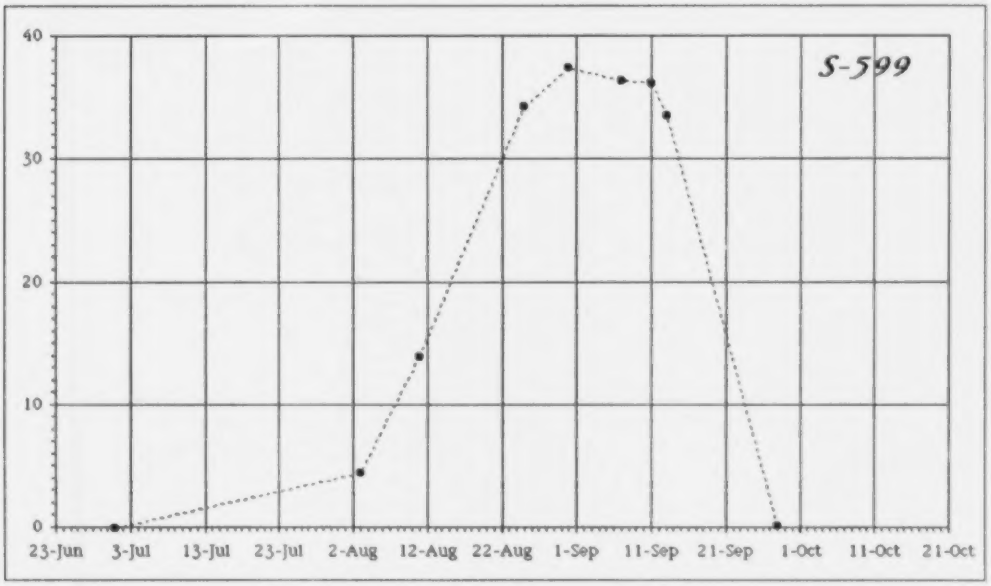
Appendix 2. Temperature analysis data

All temperature data used for the calculation of STO tag deviation from linear prediction. KM is the location of the radio (STO) tagged fish, U/S and D/S are the nearest upstream and downstream temperature logger site.

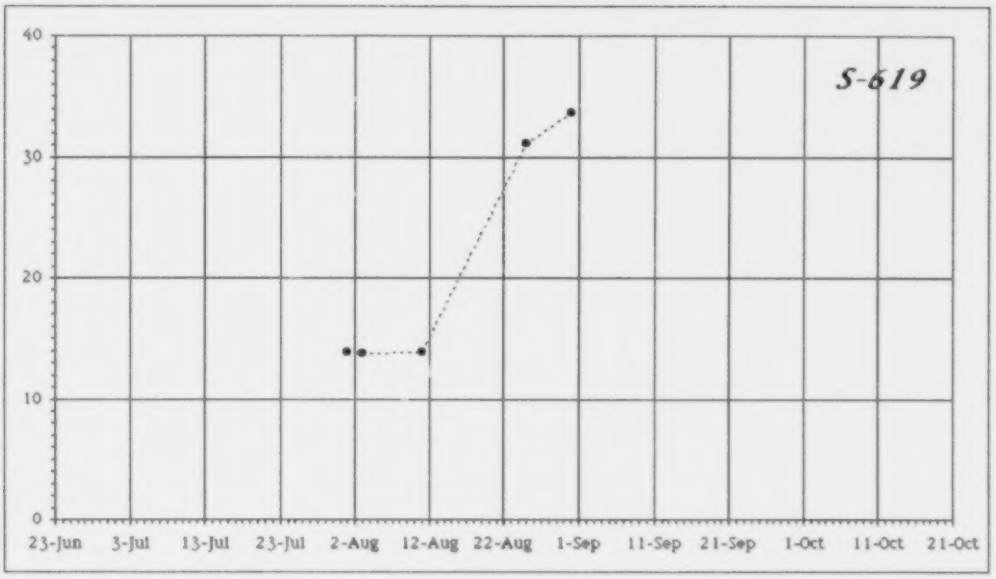
Tag	Date	Time	Tag Temp.	KM	U/S #	U/S Temp	D/S #	D/S Temp	predicted temp @ fish	difference
S-619	3-Aug	8:37	8.7	13.8	3	4.38	2	7.46	6.30	2.4
S-660	3-Aug	8:39	8.1	15.8	3	4.38	2	7.46	5.89	2.2
S-640	3-Aug	8:41	7.3	13.9	3	4.38	2	7.46	6.28	1.0
S-761	3-Aug	8:46	6.6	19.1	3	4.38	2	7.46	5.21	1.4
S-680	3-Aug	8:52	6.8	19.5	3	4.38	2	7.46	5.12	1.7
S-701	3-Aug	8:57	7.9	23.0	3	4.38	2	7.46	4.40	3.5
S-701	11-Aug	15:18	9.4	32.9	4	8.71	3	7.49	8.25	1.2
S-680	11-Aug	15:49	9.2	20.7	3	7.64	2	9.15	7.88	1.3
S-761	11-Aug	15:54	9.2	19.7	3	7.64	2	9.15	7.98	1.2
S-599	11-Aug	16:21	10.4	13.9	3	7.64	2	9.46	8.76	1.6
S-619	11-Aug	16:24	11.0	13.9	3	7.64	2	9.46	8.76	2.2
S-640	11-Aug	16:26	9.5	13.9	3	7.96	2	9.46	8.89	0.6
S-660	11-Aug	16:34	10.3	15.9	3	7.96	2	9.46	8.68	1.6
S-660	25-Aug	11:17	9.1	22.8	3	6.56	2	7.92	6.59	2.5
S-761	25-Aug	11:19	8.4	23.5	4	6.54	3	6.56	6.56	1.8
S-619	25-Aug	11:27	8.8	31.1	4	6.54	3	6.56	6.55	2.3
S-599	25-Aug	13:27	8.3	34.2	4	7.17	3	8.11	7.45	0.9
S-761	31-Aug	12:34	7.1	23.5	4	5.77	3	7.64	7.59	-0.5
S-619	31-Aug	12:40	6.7	33.6	4	5.77	3	7.64	6.40	0.3
S-599	31-Aug	12:50	6.4	37.4	4	5.77	3	7.64	5.95	0.5
S-680	7-Sep	11:37	8.6	14.8	3	9.65	2	7.76	8.60	0.0
S-599	7-Sep	11:53	8.0	36.3	4	7.01	3	9.65	7.44	0.6
S-660	7-Sep	15:04	10	32.5	4	8.09	3	11.2	9.35	0.7
S-660	8-Sep	10:38	8.7	32.4	4	5.92	3	9.03	7.20	1.5
S-701	11-Sep	14:06	8.0	10.0	3	8.11	2	6.83	6.98	1.0
S-599	11-Sep	14:37	7.6	36.1	4	6.54	3	8.57	6.90	0.7
S-660	12-Sep	8:34	7.4	15.7	3	6.72	2	6.05	6.39	1.0
S-599	13-Sep	14:19	7.5	33.5	4	7.78	3	10.43	8.69	-1.2
S-660	13-Sep	16:27	10.0	15.7	3	11.2	2	8.07	9.65	0.4
S-701	13-Sep	16:34	9.4	9.9	3	11.2	2	8.22	8.56	0.8

Appendix 3. Individual movement patterns

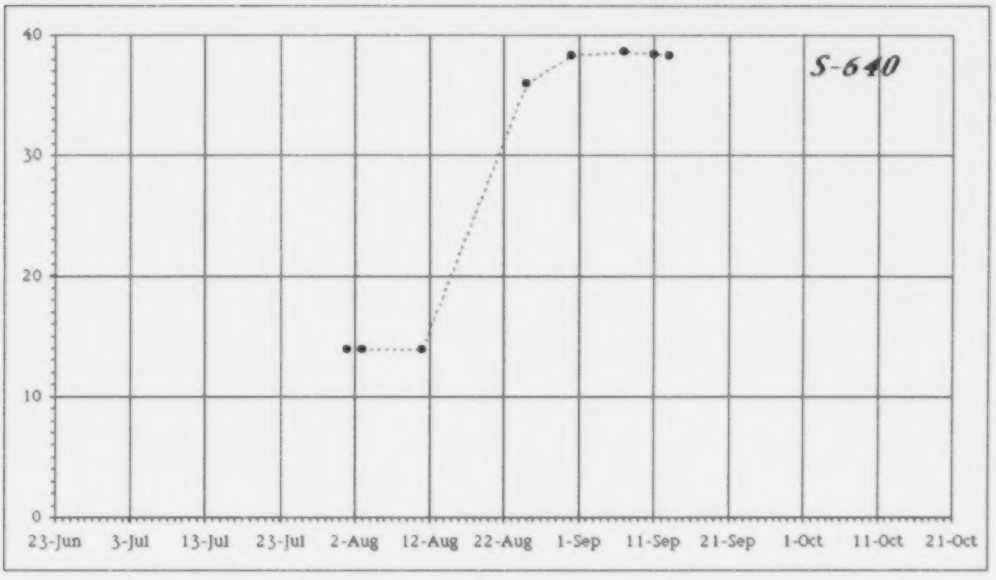
The movement patterns of bull trout having > 3 receptions are presented here. Bull trout tagged in Graham Lake were S-779, RT 14-51, RT 14-69. Bull trout summary data are presented in Table 2 and Appendix 1. The y-axis indicates kilometer location .



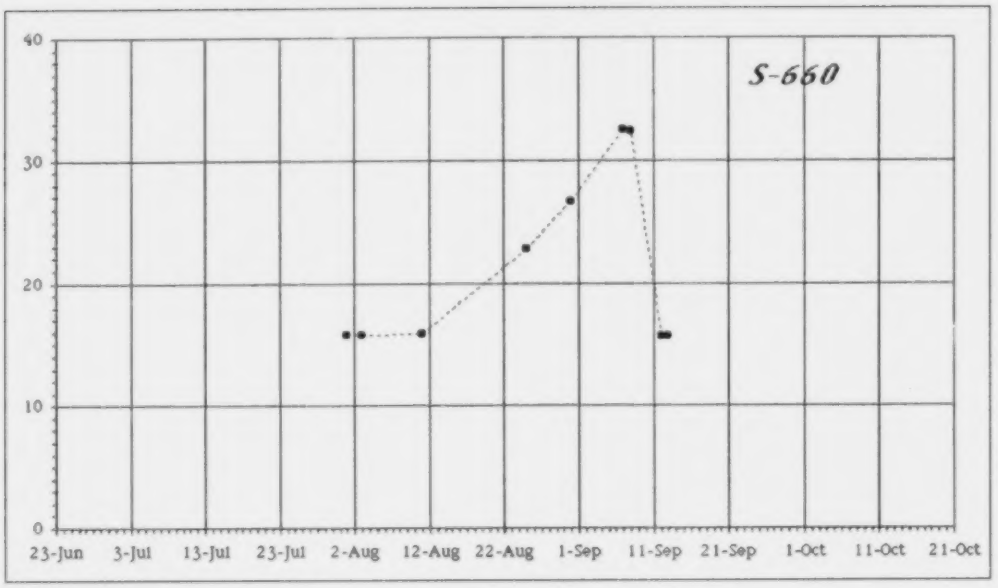
S-599 Davis. Exhibited spawning migration, returned to reservoir. Redds observed near strongest detected signal on September 11 tracking flight.



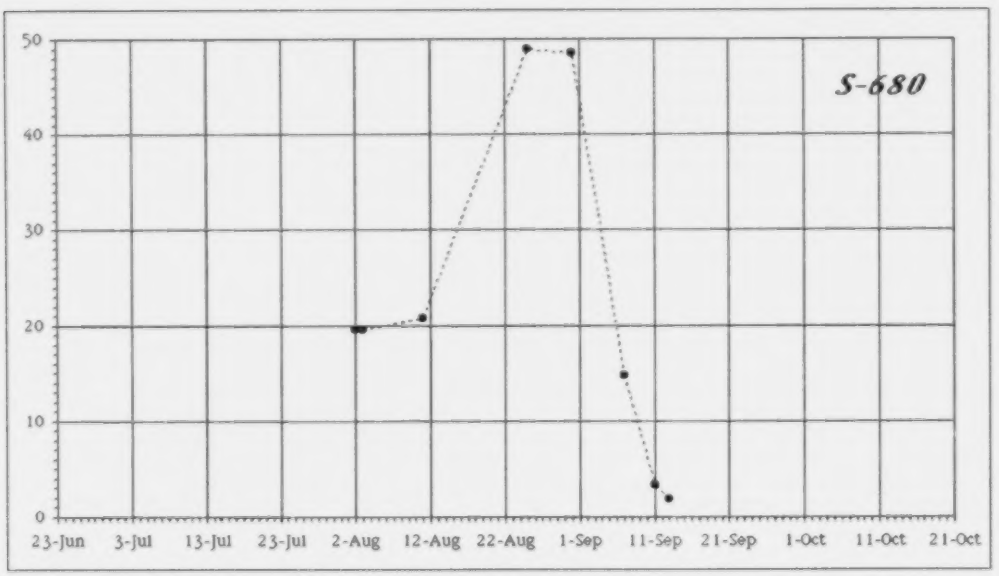
S-619 Davis. Last detected August 31. Presumed to have spawned and returned to reservoir.



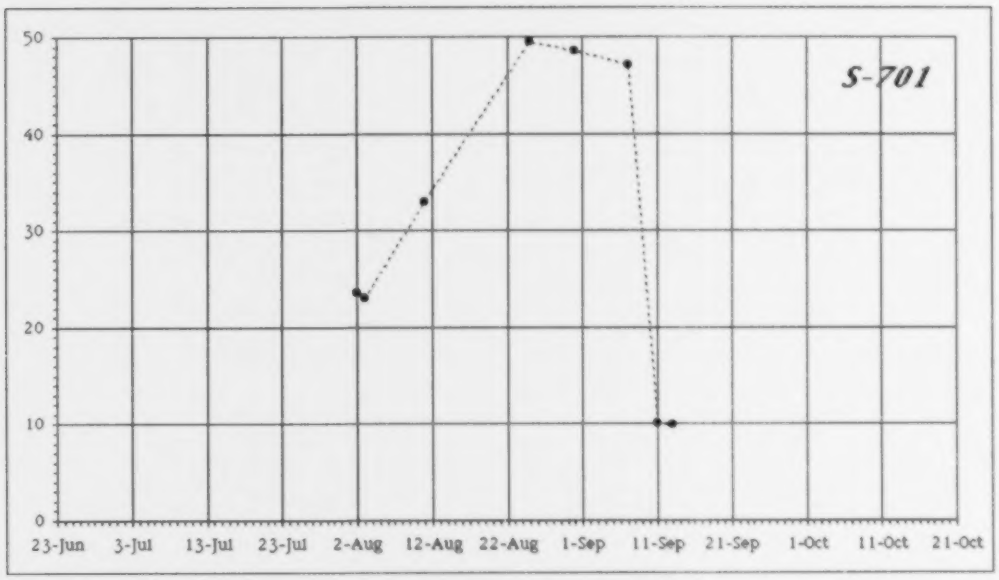
S-640 Davis. Presumed to have spawned in tributary 616 then returned to reservoir. Last tracked 13 September.



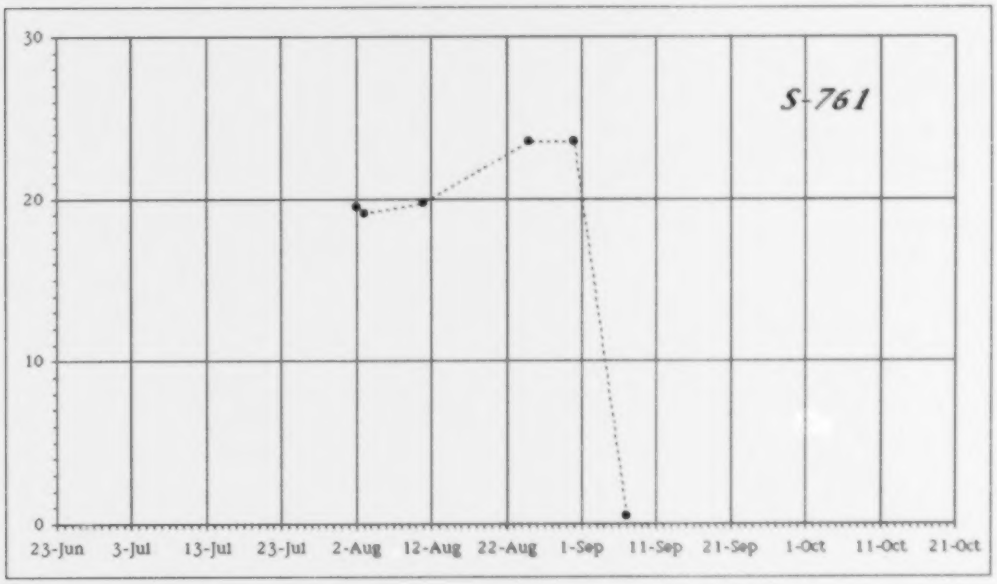
S-660 Davis. Presumed to have spawned and ultimately returned to reservoir.



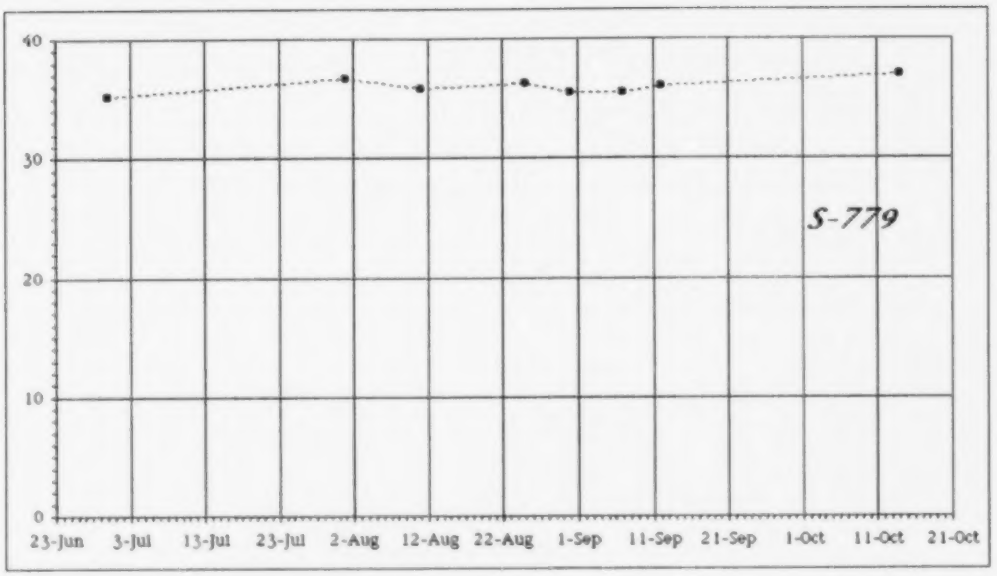
S-680. Presumed to have spawned. Returned to reservoir.



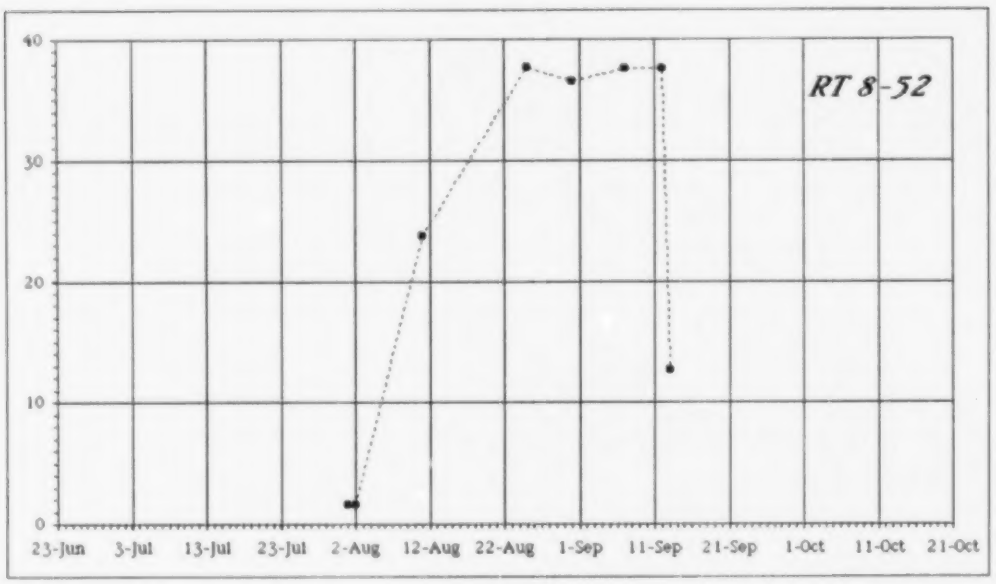
S-701 Davis. Presumed to have spawned. Returned to reservoir.



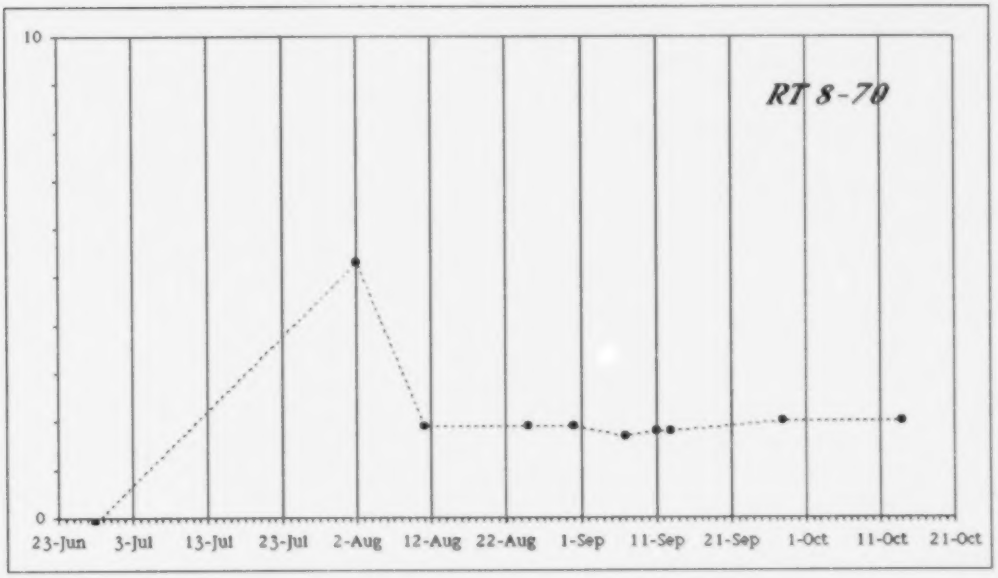
S-761 Davis. May have spawned, returned early to bridge crossing lower Davis by Sep 7.



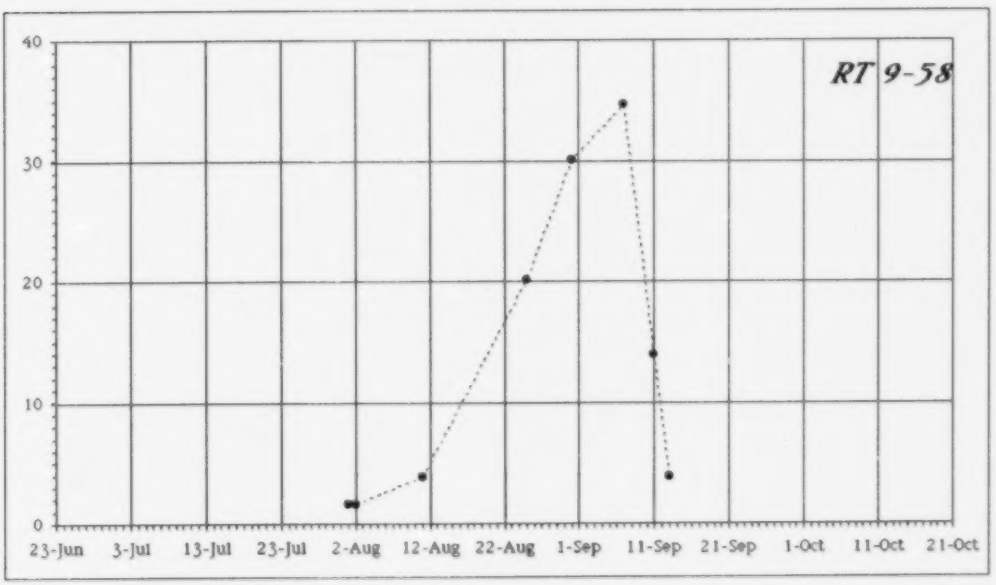
S-779 Graham Lake. Did not exhibit spawning movements, remained mobile in Graham Lake.



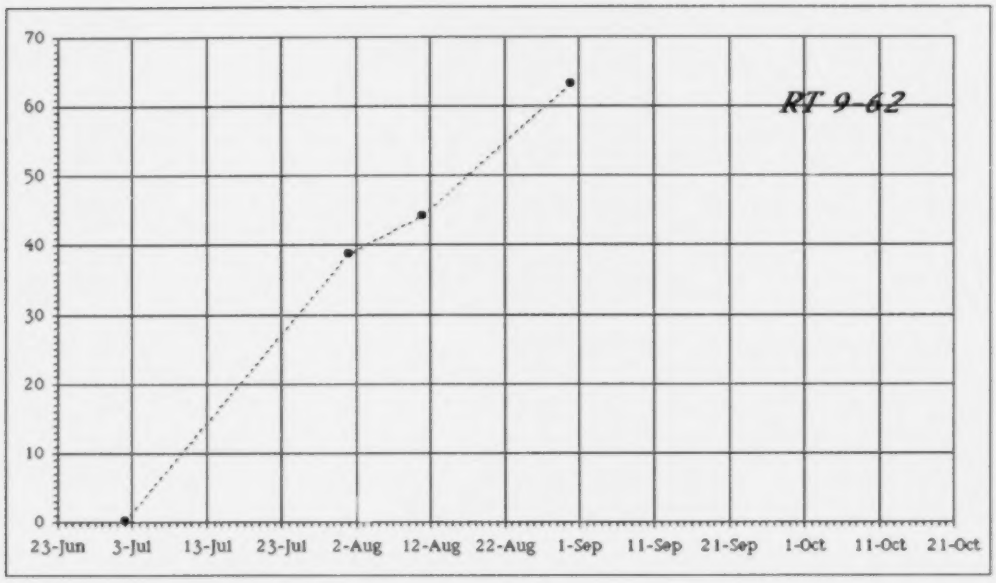
8-52 Davis. Presumed to have spawned, rapid downstream migration.



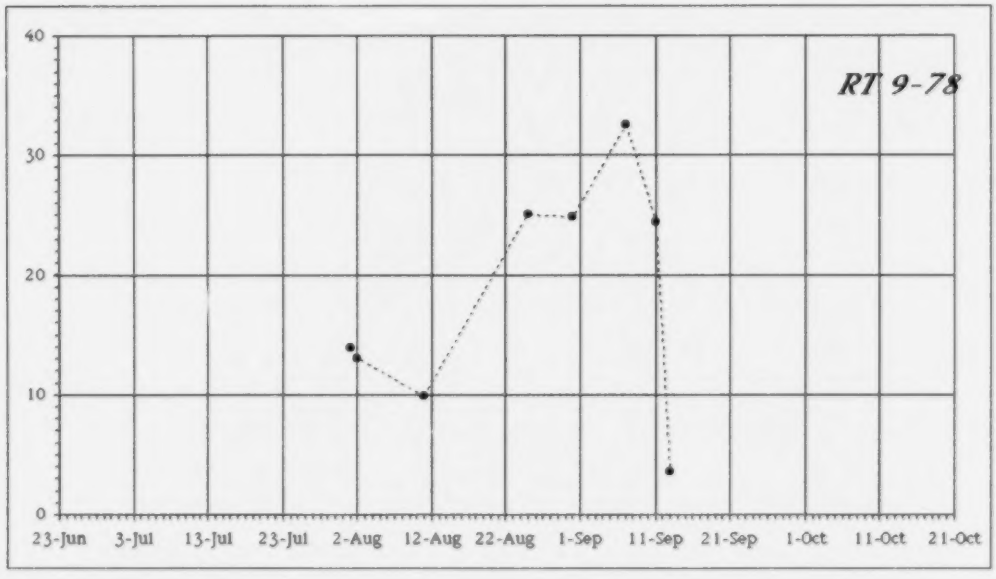
8-70 Davis. Appears to have survived surgery, but likely died thereafter. Possible angling mortality.



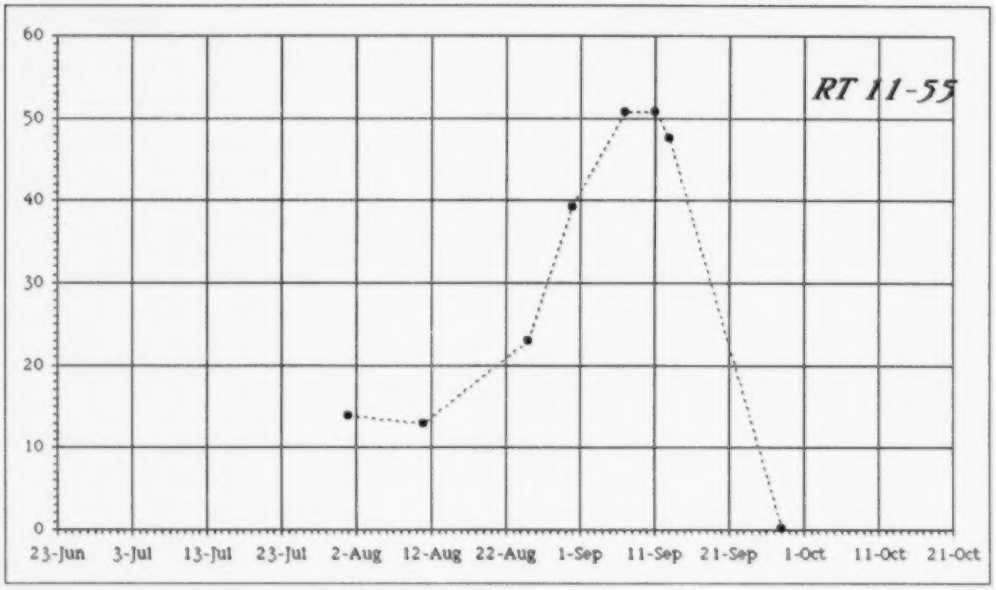
9-58 Davis. Presumed to have spawned and returned to reservoir.



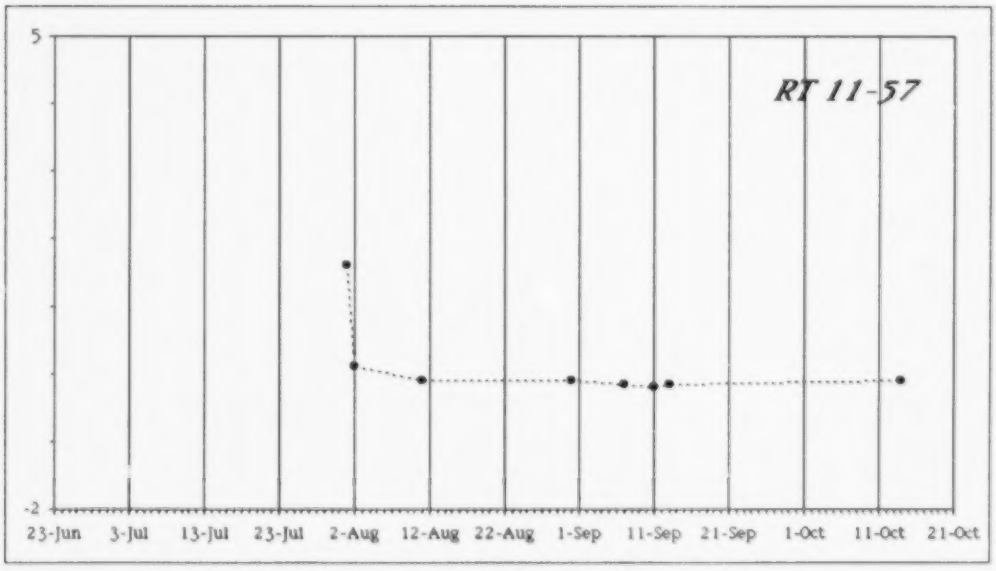
9-62 Chowika. Extensive migration from Davis Bay to upper Chowika. Last detected August 31. Subsequent flights (Sep 7, 11) failed to locate, presumed to have spawned and returned to reservoir.



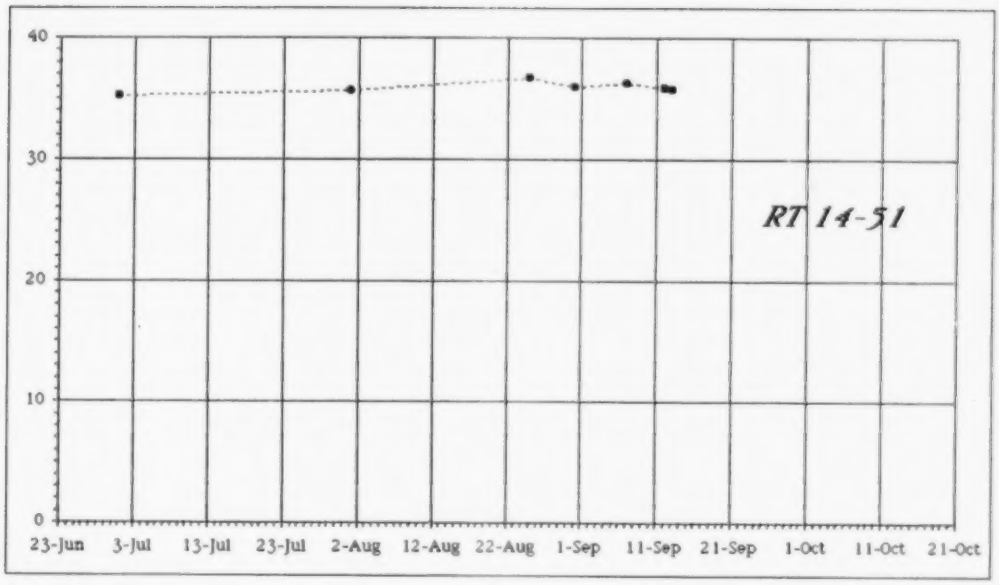
9-78 Davis. Initially moved downstream following surgery, then presumed to have spawned before returning to reservoir.



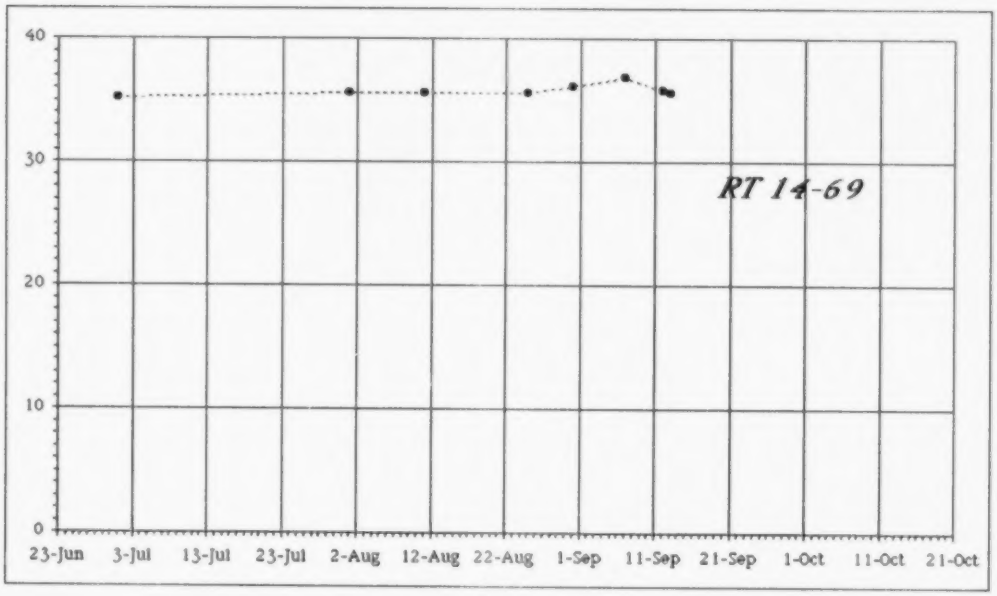
11-55 Davis. Presumed to have spawned. Returned to reservoir.



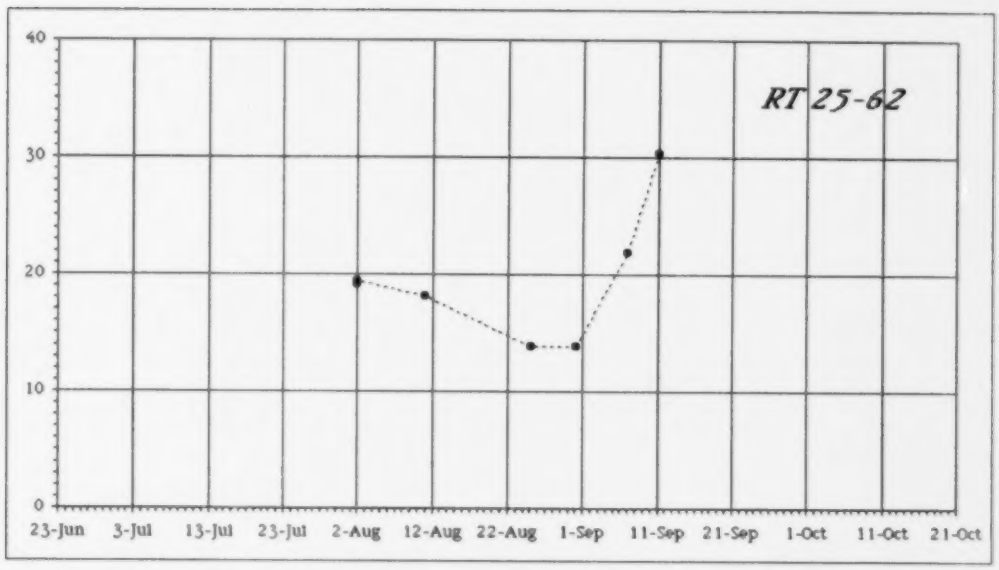
11-57 Davis Bay. Captured by angler 1 day after surgery. Presumed to have died of angling related stress.



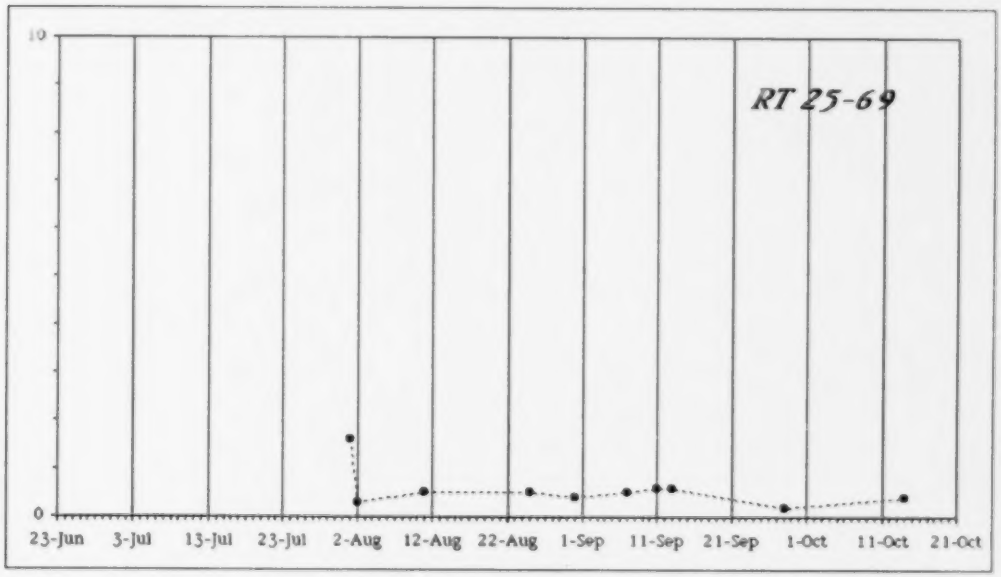
14-51 Graham Lake. Presumed to have spawned in Trib. 657, then returned to Graham Lake.



14-69 Graham Lake. Presumed to have spawned in Trib. 657, then returned to Graham Lake.



25-62 Davis. Presumed to have spawned and returned early to reservoir.



25-69 Davis. No movements. Presumed mortality.